

STATE OF CALIFORNIA  
DEPARTMENT OF WATER RESOURCES  
**OROVILLE DAM SAFETY  
COMPREHENSIVE NEEDS ASSESSMENT**

Further Description and  
Clarification of the  
Comprehensive  
Needs Assessment  
Project

Meeting No. 2 – Oroville Dam Safety Ad Hoc Committee

October 30, 2018





From the June 27, 2017 memorandum to DSOD,  
and the June 28, 2017 letter from DWR to FERC:

*“Over the past decade, a number of efforts within the Department of Water Resources (DWR) have focused on improving the reliability of exiting appurtenances and other dam safety measures that contribute to the safety and ongoing integrity of Oroville Dam and those appurtenant structures.”*

*“As key internal and consultant resources from the Spillway Recovery Design Phase become available, DWR plans to reengage these various efforts and formally initiate a Comprehensive Needs Assessment to identify and prioritize dam safety enhancements for the future, which would include enhanced instrumentation if deemed a necessary improvement.”*







# Definition of CNA

“...to identify measures to restore and improve, as necessary, the safety and reliability of Oroville Dam and the appurtenant structures.”

## DEPARTMENT OF WATER RESOURCES

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January 12, 2018

Mr. Frank L. Blackett, P.E.  
Regional Engineer  
Federal Energy Regulatory Commission  
100 First Street, Suite 2300  
San Francisco, California 94105-3084

FERC Project No. 2100 – Oroville Dam, Dam Safety  
Comprehensive Needs Assessment Plan and Schedule

Dear Mr. Blackett:

By letter dated June 28, 2017, the Department of Water Resources (DWR) informed the Federal Energy Regulatory Commission (FERC) of its intent to initiate a Comprehensive Needs Assessment (project) to identify measures to bolster the safety and reliability of Oroville Dam and the appurtenant structures. Over the past several months, DWR has identified the following six project tasks:

- Task 1 - Alternatives Evaluation to Restore Spillway Design Capacity to Pass the Probable Maximum Flood
- Task 2 - Operations Needs Assessment to Support Development of Alternative Reservoir Outflow Enhancements
- Task 3 - Flood Control Outlet Enhanced Reliability
- Task 4 - Alternatives Evaluation for Low-level Outlet
- Task 5 - Oroville Dam Embankment Reliability and Improvements
- Task 6 - Instrumentation and Monitoring for the Oroville Dam Complex

The project is scheduled to begin January 16, 2018 and conclude by December 31, 2019. A list of prioritized dam safety and operational reliability needs will be produced through completion of the project. Those needs will then be evaluated by DWR management and scheduled as projects through normal practices and procedures. As the project progresses, the Project Manager may identify projects that provide significant public safety and risk reduction benefits. Such projects may be submitted to DWR management for early implementation. DWR will comply with FERC and other regulatory agencies' submittal, review, and approval processes as part of the implementation.



# Independent Review Board Comment

“The scope of a comprehensive project to assess the needs of Oroville Dam could be interpreted in many ways without appropriate definition of scope and context.”

## Recommendation from the IRB

M1-22 The IRB recommends that future presentations to the public and the final project report provide a description of the rationale for the tasks included in the project.





# Ad Hoc Committee Comment

- “The use of the term “Comprehensive Needs Assessment” implies a more thorough examination of needs than currently proposed via the identified six (6) tasks and may be interpreted by the public as misleading.”



# DWR Response to IRB and Ad Hoc Committee Comments

“Concur”

The Ad Hoc Committee (and IRB) make a good point that others could assume a project scope that goes beyond an infrastructure evaluation.

DWR’s October 23, 2018 letter and presentations at the Ad Hoc Committee (and IRB) Meeting No. 2 intended to clarify scope as an evaluation of Oroville Dam complex infrastructure.



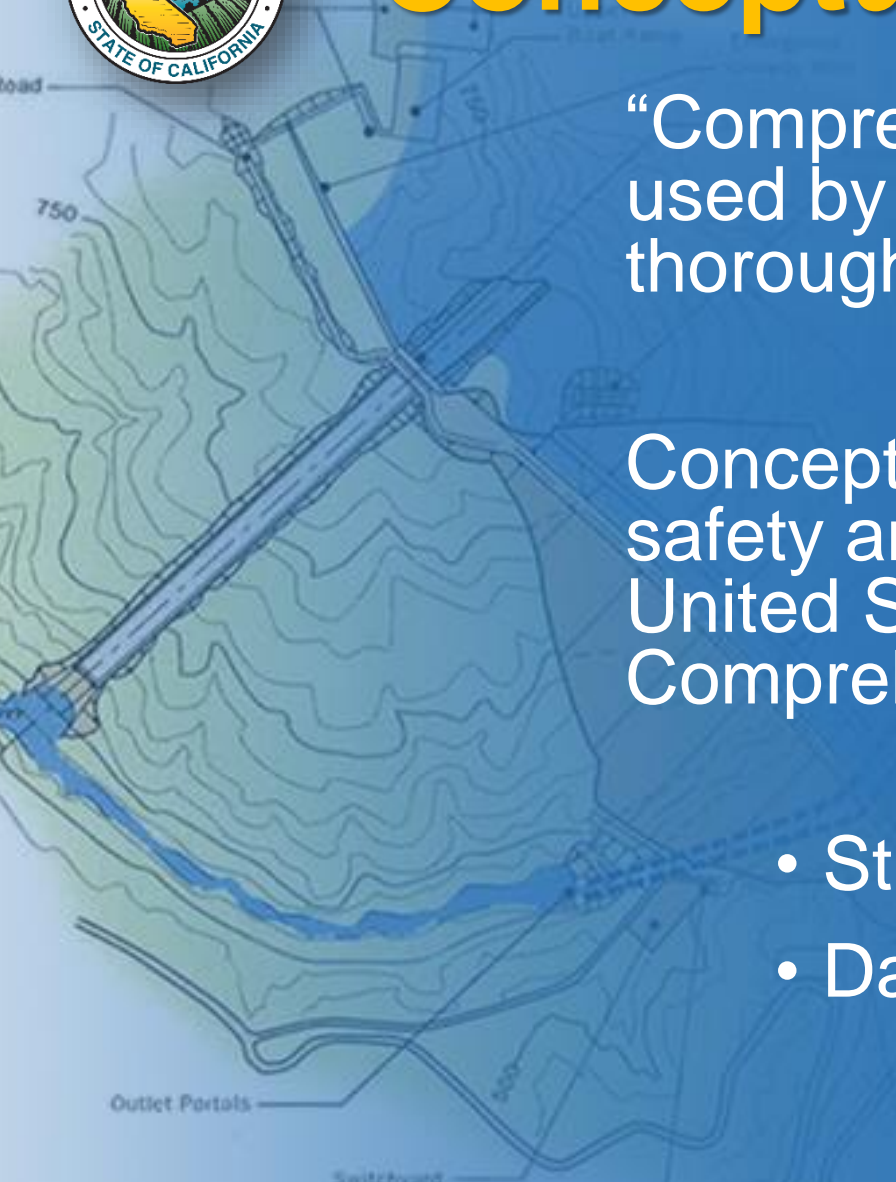


# Conceptualization

“Comprehensive Needs Assessment” title commonly used by DWR O&M Division for projects that thoroughly assess infrastructure conditions.

Conceptualized as a component-by-component dam safety and operational reliability evaluation similar to United States Bureau of Reclamation (USBR) Comprehensive Facility Review (CFR)

- Structural Facility Considerations
- Dam Safety Performance Considerations





# Structural Facility Considerations



Impounding Facility (S1)



Spillway (S2)



Outlet (S3)

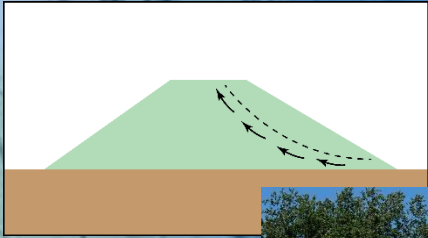


Instrumentation (S4)





# Dam Safety Performance Considerations



Stability (P1)



Spillway Safety and capacity (P2)



Outlet Discharge Capacity and Integrity (P3)



Seepage and Leakage (P4)



Surveillance and Monitoring (P5)



# Dam Safety Focus Designations

## Critical Structures

S1	Impounding Facility
S2	Spillway
S3	Outlets
S4	Instrumentation

## Performance

P1	Stability
P2	Spillway Safety and Capacity
P3	Outlet (Low-Level and High-Level)
P4	Seepage and Leakage
P5	Surveillance and Monitoring





# Comparison of CNA to General Approach for Dam Safety Evaluations

CNA TASK	AREA of FOCUS
Task 1 – Spillway Alternatives	S1, S2, P1, P2, P4, P5
Task 2 – Operations Needs Assessment	S2, S3, P2, P3
Task 3 – FCO Enhanced Reliability	S1 – S4, P1 – P5
Task 4 – Low Level Outlet Alternatives	S1, S3, P1 – P5
Task 5 – Embankment Reliability and Improvements	S1, P1, P4, P5
Task 6 – Instrumentation and Monitoring	S4, P1 – P5



# IFT Lessons Learned – Concurrence

*“ The IFT offers six industry-level lessons to be learned that it has identified during the investigation. These lessons apply generally to dam safety practice in the United States and are related to:*

- Physical inspections (all tasks except Task 2 – Operations Needs Assessment)*
- Comprehensive facility reviews (all tasks)*
- Regulatory compliance (all tasks)*
- Potential Failure Mode Analyses (PFMAs) (all tasks)*
- Consideration of appurtenant structures (all tasks)*
- Owners’ dam safety programs and dam safety culture (DWR Management Initiative) ”*





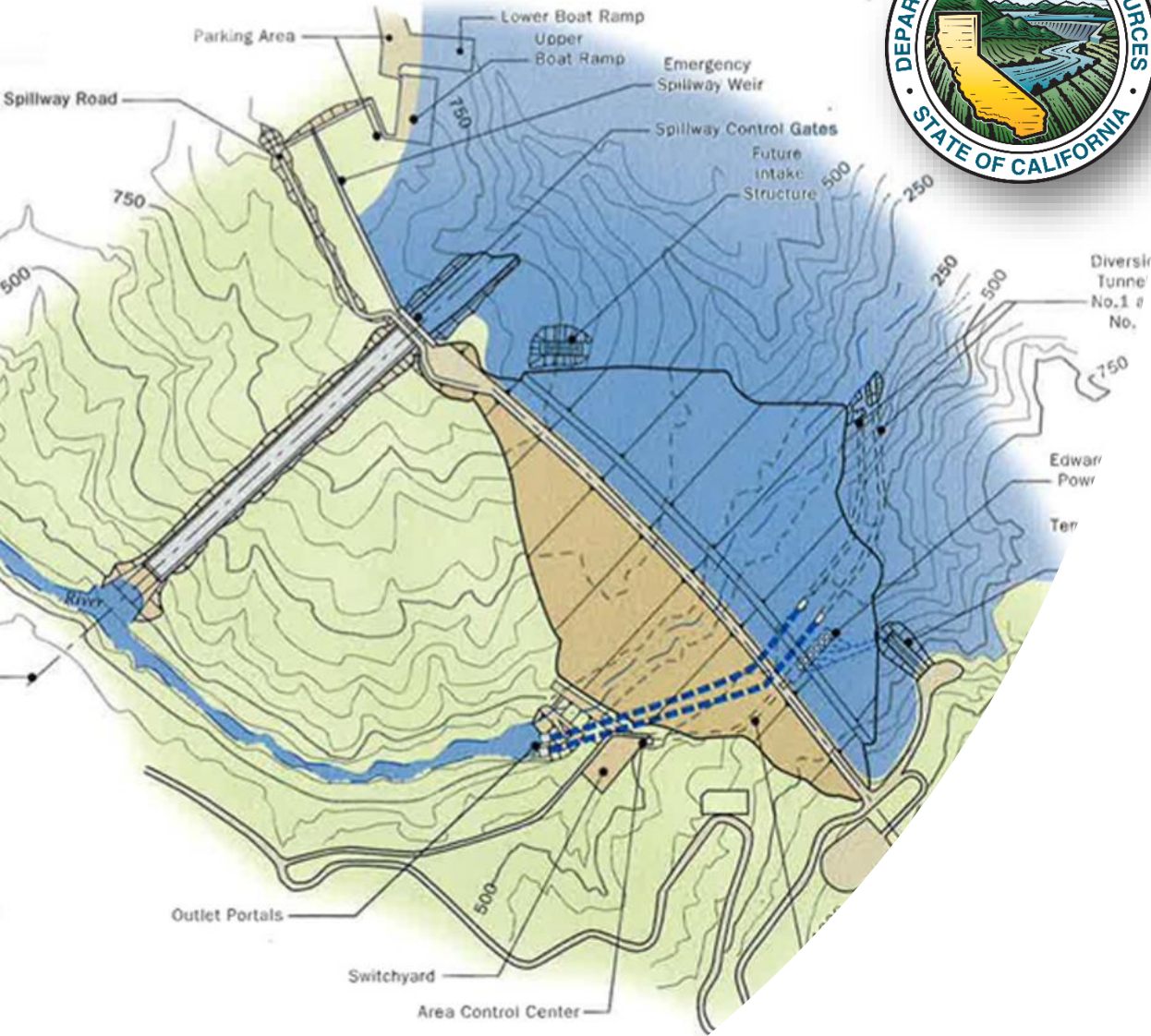
# Related Topics and Venues

<b>General Organizational, Regulatory, and Industry Factors</b>	DWR has provided its response to the General Organizational, Regulatory, and Industry Factors identified by the Independent Forensics Team in three separate letters to FERC. In these letters, DWR outlines immediate, near-term, and long-term initiatives to advance the SWP Dam Safety Program. This advancement will be a multi-year, continuous improvement effort, and will be captured in annual updates to the SWP Owner's Dam Safety Program documents that are filed at FERC.
<b>Water Control Manual</b>	A formal update to the WCM is under the authority of the USACE. It is anticipated that the process for updating the WCM will take multiple years and is dependent upon the adoption of potential infrastructural changes resulting from the CNA process.
<b>Forecast Informed Reservoir Operations</b>	DWR has been engaged with the USACE and Yuba County Water Agency on a Forecast Informed Operations Program and all three agencies will consider adopting some aspects of Forecast Informed Operations during the development of the WCM updates.
<b>Facility Security</b>	DWR closely coordinates efforts to ensure the security of the facility with appropriate agencies such as the Department of Homeland Security, the California Office of Emergency Services, the California Highway Patrol, the Butte County Sheriff, and California Department of Parks and Recreation law enforcement personnel. All security protocols meet the requirements of these agencies. As required by these agencies, details about these efforts are not made available to the public.



Questions?





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# Comprehensive Needs Assessment: Project Integration and Evaluation

Meeting No. 2 – Oroville Dam Safety Ad Hoc Committee  
October 30, 2018





# Initially Identified Project Tasks

1. Alternatives Evaluation to Restore Spillway Design Capacity to Pass the Probable Maximum Flood
  2. Operations Needs Assessment to Support Development of Alternative Reservoir Outflow Enhancements
  3. Flood Control Outlet (FCO) Enhanced Reliability
  4. Alternatives Evaluation for Low-level Outlet
  5. Oroville Dam Embankment Reliability and Improvements
  6. Instrumentation and Monitoring for the Oroville Dam Complex
- Integration team



# Project Development

- Started as six relatively independent technical tasks.
- Originally envisioned with many task-level workshops and deliverables.
- CNA project leadership and IRB recognized need for project-level integration.
- Several key activities moved from task level to project level.
- HR 5895-Federal Legislation Requiring Level 2 Risk Analysis.
- Adjustments made to the workplan schedule to optimize use of planning study approach.





# Project Integration Tasks

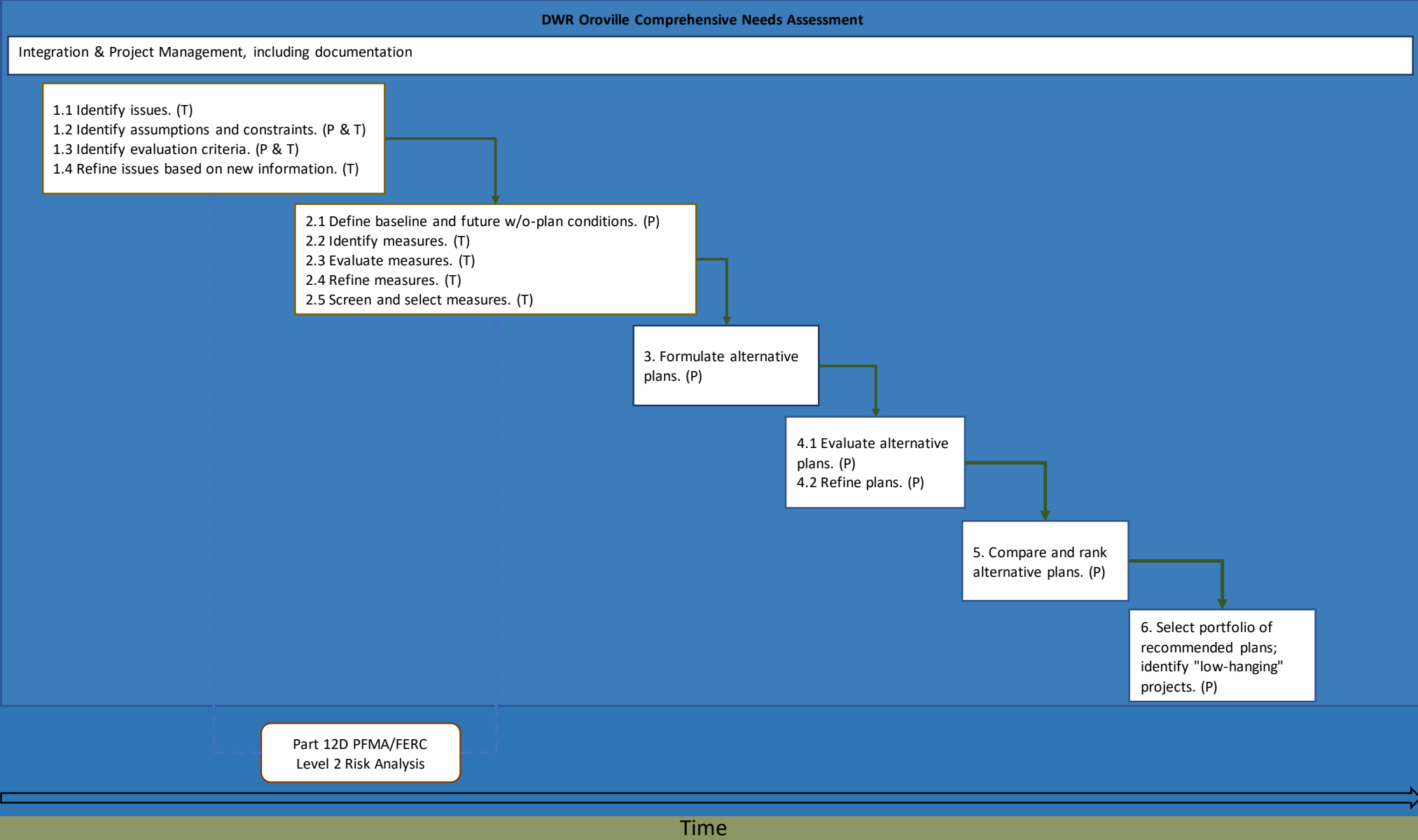
- Developing CNA's guiding principles.
- Developing CNA project-level management plan.
- Developing and tracking comprehensive CNA schedule.
- Tracking Independent Review Board's recommendations and CNA's responsive actions.
- Determining current and future without-project conditions.
- Identifying what's working well.
- Applying value analysis to the CNA.
- Developing and enforcing CNA quality management plan.
- Developing strategy for adapting to climate change.
- Outlining final report, including glossary.



# CNA Infrastructure Planning Study?

1. Identify objectives, constraints, opportunities and needs.
2. Identify measures to address those needs.
3. Combine measures to formulate alternative plans.
4. Evaluate alternative plans with agreed-upon metrics.
5. Compare and rank alternative plans.
6. Recommend alternative plans for consideration.

# CNA Project Approach Diagram







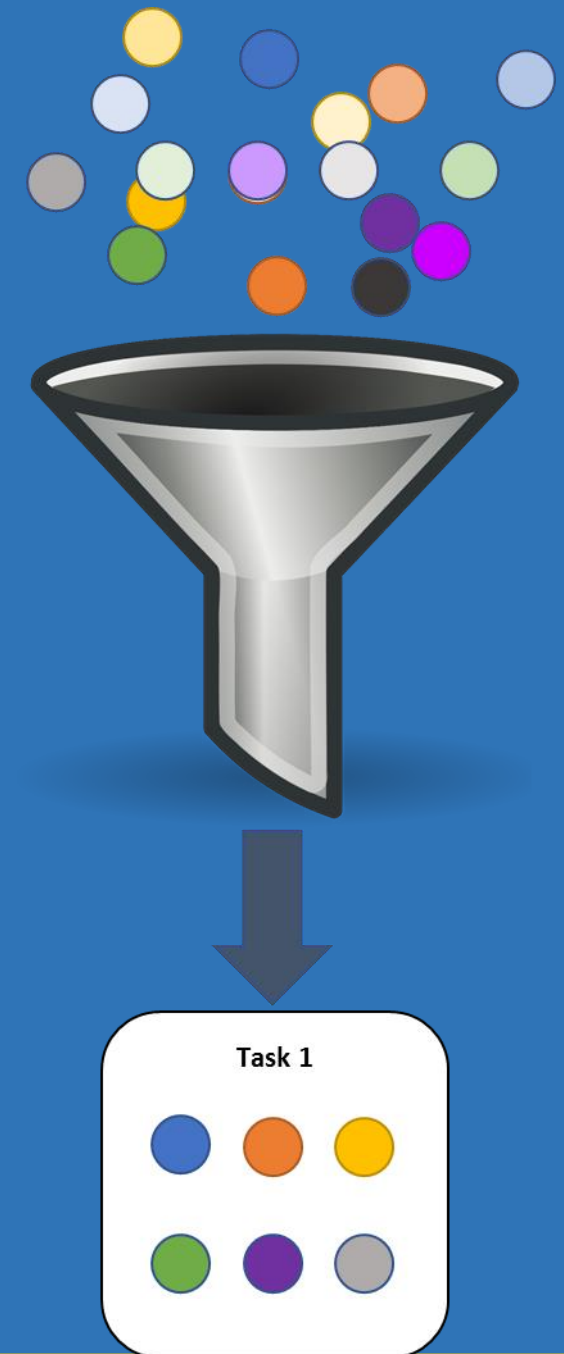
# CNA Measures

- A feature or activity that can be implemented to address one or more dam safety issues or opportunities.
- Examples:
  - Modified or new spillway structures.
  - New higher-capacity low-level outlet.
  - Addition of piezometers to embankment.



# How are Measures Identified and Screened?

- Measures identified by task teams.
- Measures screened at task level to eliminate inferior proposed measures.
- Best measures carried forward from tasks to project level for integration into plans.





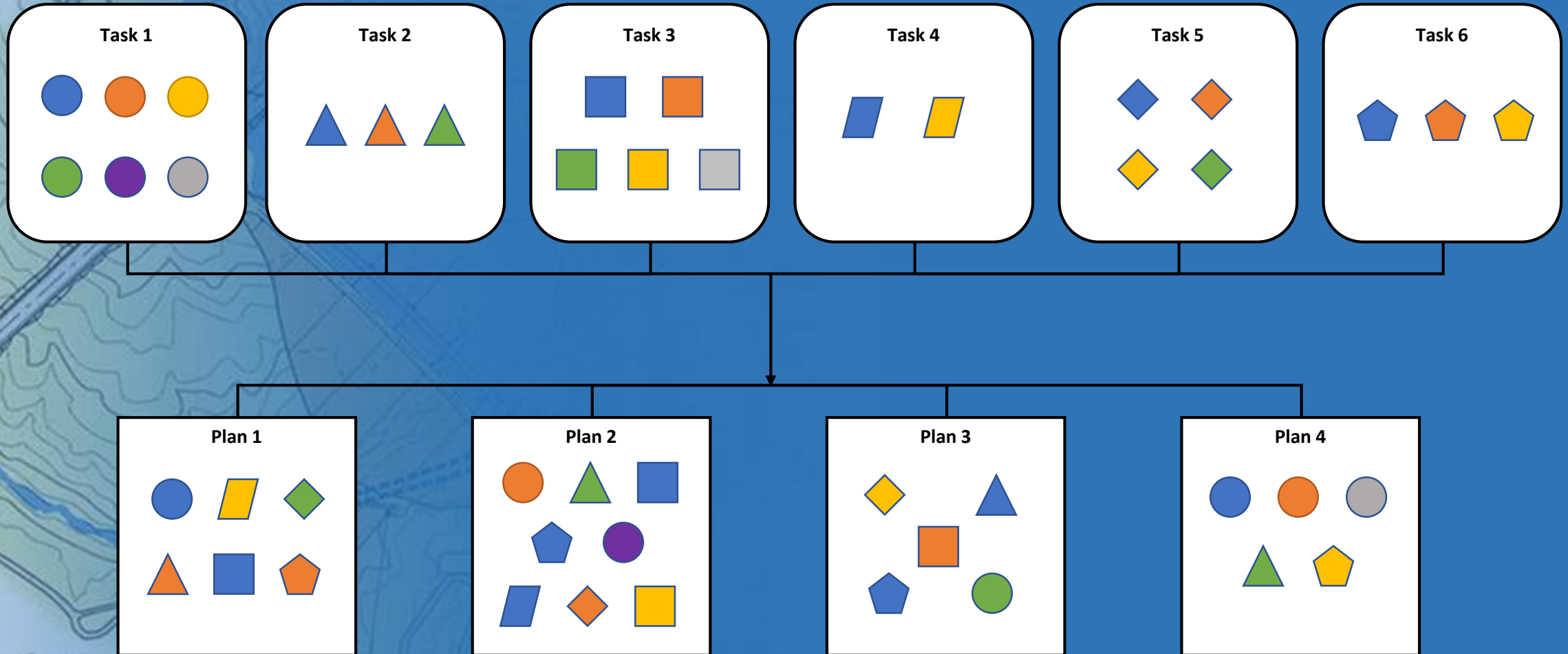
# CNA Alternative Plans

- Integrated set of measures that meets objectives at some level, satisfies constraints.
- May include no measures from some tasks and multiple measures from others.
- Formulated by project team, with collaboration and cooperation of task managers and staff.





# How are Measures Combined to Create Alternative Plans?





# Outcome and Deliverables

- A *portfolio of alternative plans*, each of which meets goal of CNA.
- An assessment of effectiveness of each alternative plan, using a broad set of evaluation criteria.
- Identification of alternative plans that perform best in different “themes.”
- Recommendations for plans or measures that can be implemented early to restore and enhance safety and reliability.



# Evaluation Criteria Framework

The CNA team needs to:

1. Estimate risk reduction attributable to alternative plans.
2. Use practicable approach for risk analysis (semi-quantitative).
3. Use criteria consistent with DWR O&M Asset Management Risk Management Framework criteria.
4. Consider other benefits gained or consequences avoided.





# Draft Evaluation Criteria

Item no.	Criterion
1	Protects public and worker safety
2	Complies with dam safety regulations
3	Improves operational flexibility (water delivery / other SWP purposes)
4	Improves operational reliability (water delivery / other SWP purposes)
5	Follows conventional design approaches
6	Follows conventional construction approaches
7	Requires conventional O&M activities
8	Navigates permitting issues successfully
9	Assures water and power delivery
10	Implements plan in a timely manner
11	Minimizes total cost (e.g., construction, O&M, failure to perform, opportunity cost)
12	Achieves robustness, redundancy, resourcefulness, rapidity, resiliency
13	Provides other public benefits



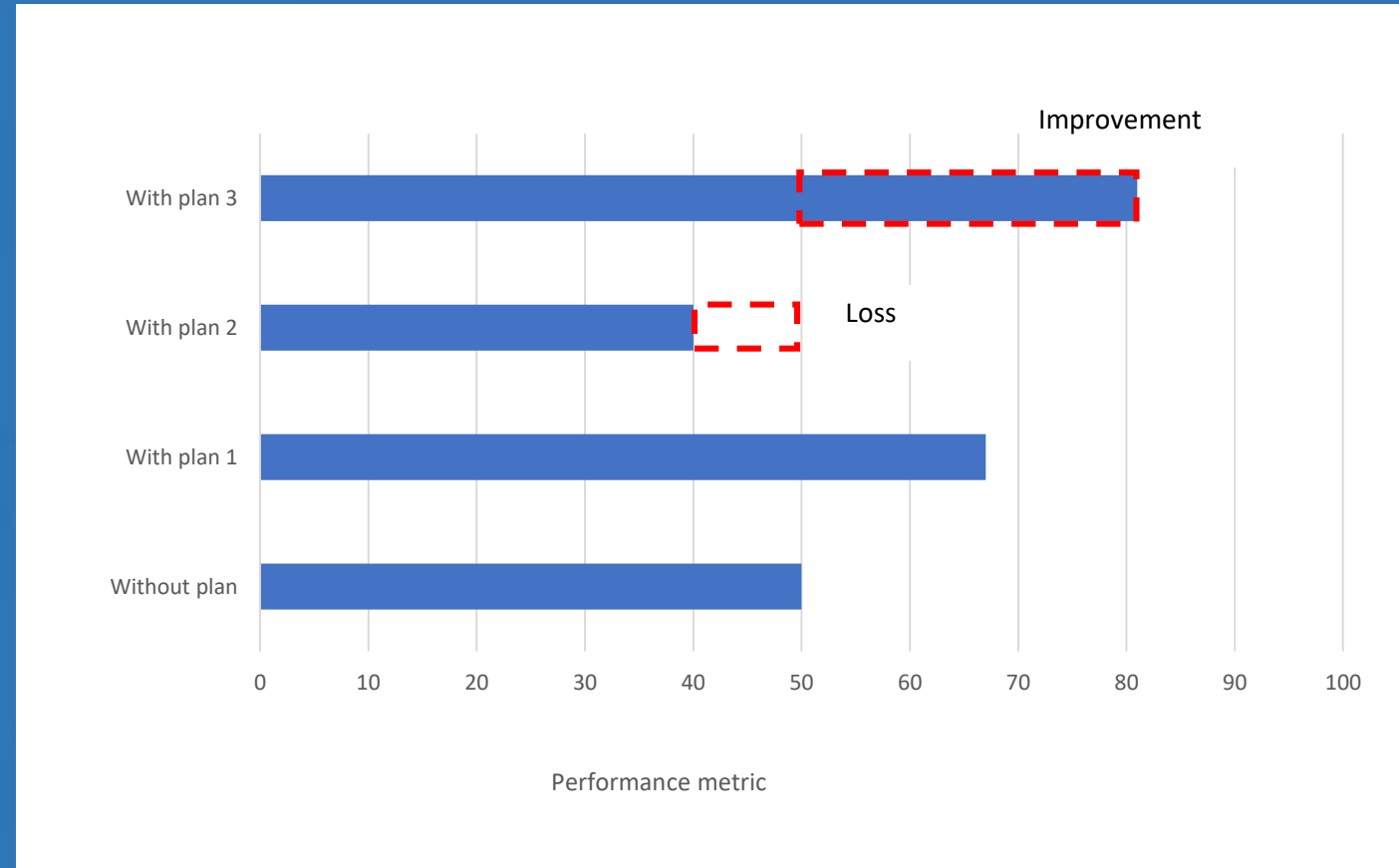
# How Will Risk Analyses be Conducted?

Likelihood								
Likely to occur 10 times a year	7	7	14	21	28	35	42	49
Likely to occur within 1 year	6	6	12	18	24	30	36	42
Likely to occur within 3 years	5.5	5.5	11	16.5	22	27.5	35	38.5
Likely to occur within 10 years	5	5	10	15	20	25	30	35
Likely to occur within 30 years	4.5	4.5	9	13.5	18	22.5	26	31.5
Likely to occur within 100 years	4	4	8	12	16	20	24	
Likely to occur within 1000 years	3	3	6	9	12	15	18	<b>B</b>
Likely to occur within 10,000 years	2	2	<b>A</b>	6	8	10	12	14
Likely to occur within 100,000 years	1	1	2	3	4	5	6	7
		Consequence						
		1	2	3	4	5	6	7
		Insignificant	Minor	Moderate	High	Major	Extreme	Catastrophic



# How are Alternative Plans Compared (Step 5)?

1. Compare without-plan and with-plan performance over 50-year lifespan for each criterion to identify improvement.
2. Use multi-criteria decision-making technique(s) to provide decision makers with information about advantages and disadvantages of each plan.
3. Identify obvious beneficial improvements for early implementation.







# What is the Outcome of Step 6?

- Recommendation of highest ranking Alternative Plans.
- Identification of early implementation measures or projects.





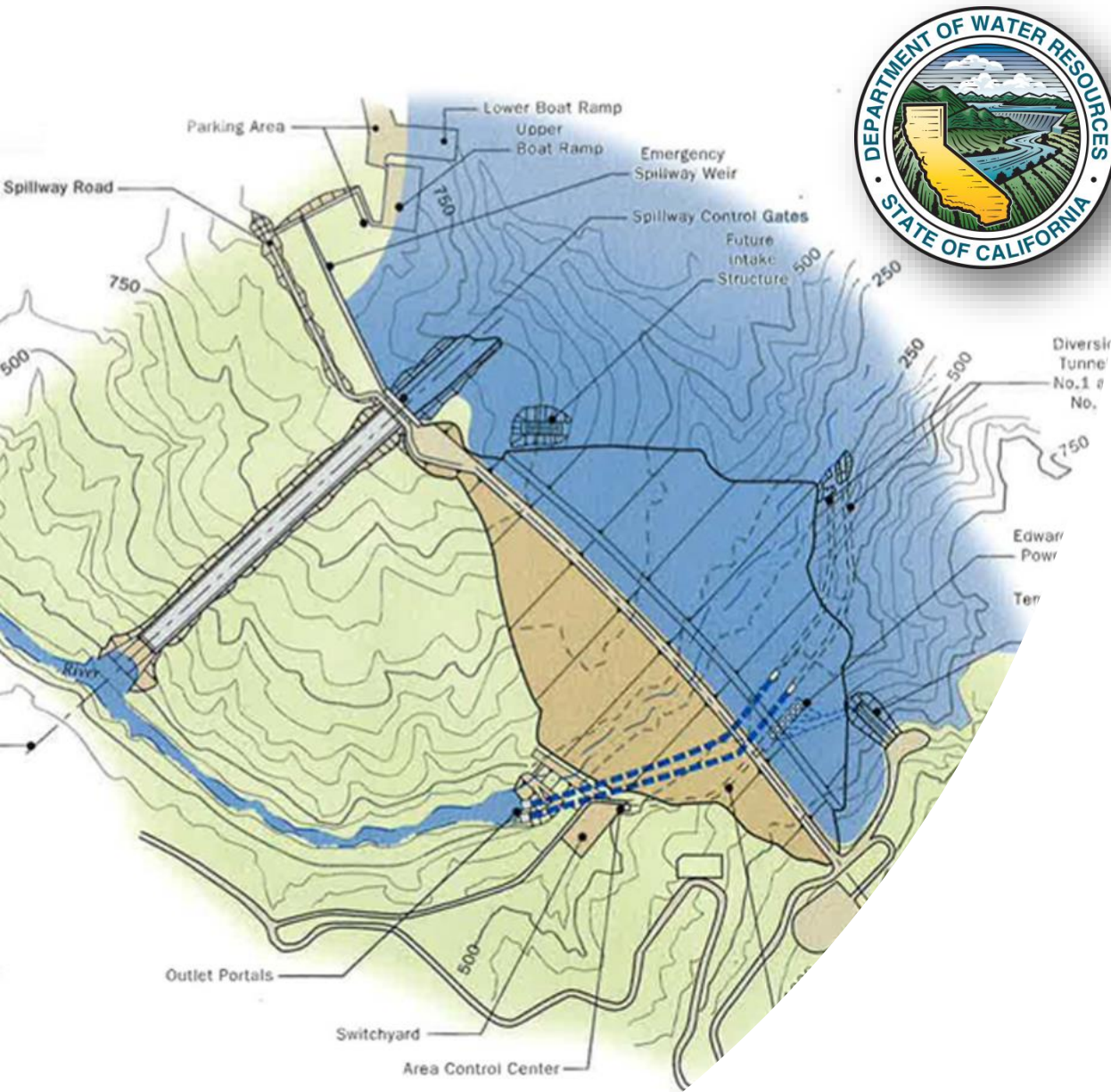
	2017												2018												2019												2020											
	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC					
Project Commitment (June 28, 2017)																																																
Project Conceptualization																																																
Project Scoping																																																
Draft Project Management Plans																																																
Contracting and Staffing																																																
IRB Appointments																																																
Integrated Project Approach Development																																																
Project Management Plan Adjustments																																																
1.1 Identify Issues																																																
1.2 Identify Assumptions and Constraints																																																
1.3 Identify Evaluation Criteria																																																
1.4 Refine Issues Based on New Information																																																
2.1 Define Baseline and Future Without Plan Conditions																																																
R Part 12D PFMA/SQRA																																																
2.2 Identify Measures to Address Issues																																																
2.3 Evaluate Measures Based on Evaluation Criteria																																																
2.4 Refine Measures Based on Evaluation Outcomes																																																
2.5 Screen and Select Measures for Next-Step Formulation																																																
3.1 Formulate Alternative Plans																																																
4.1 Evaluate Alternative Plans with CNA SQRA																																																
4.2 Refine Plans																																																
5.1 Compare and Rank Alternative Plans																																																
6.1 Select Portfolio of Recommended Plans																																																
Draft Report																																																
Final Report																																																

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# Questions?

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# CNA Task 2 and other Flood Operations Activities

Ad Hoc Meeting

October 30, 2018





# Overview

- 2018-19 Winter Operations Plan
- CNA – Task 2
- USACE Water (Flood) Control Manual (WCM) Update



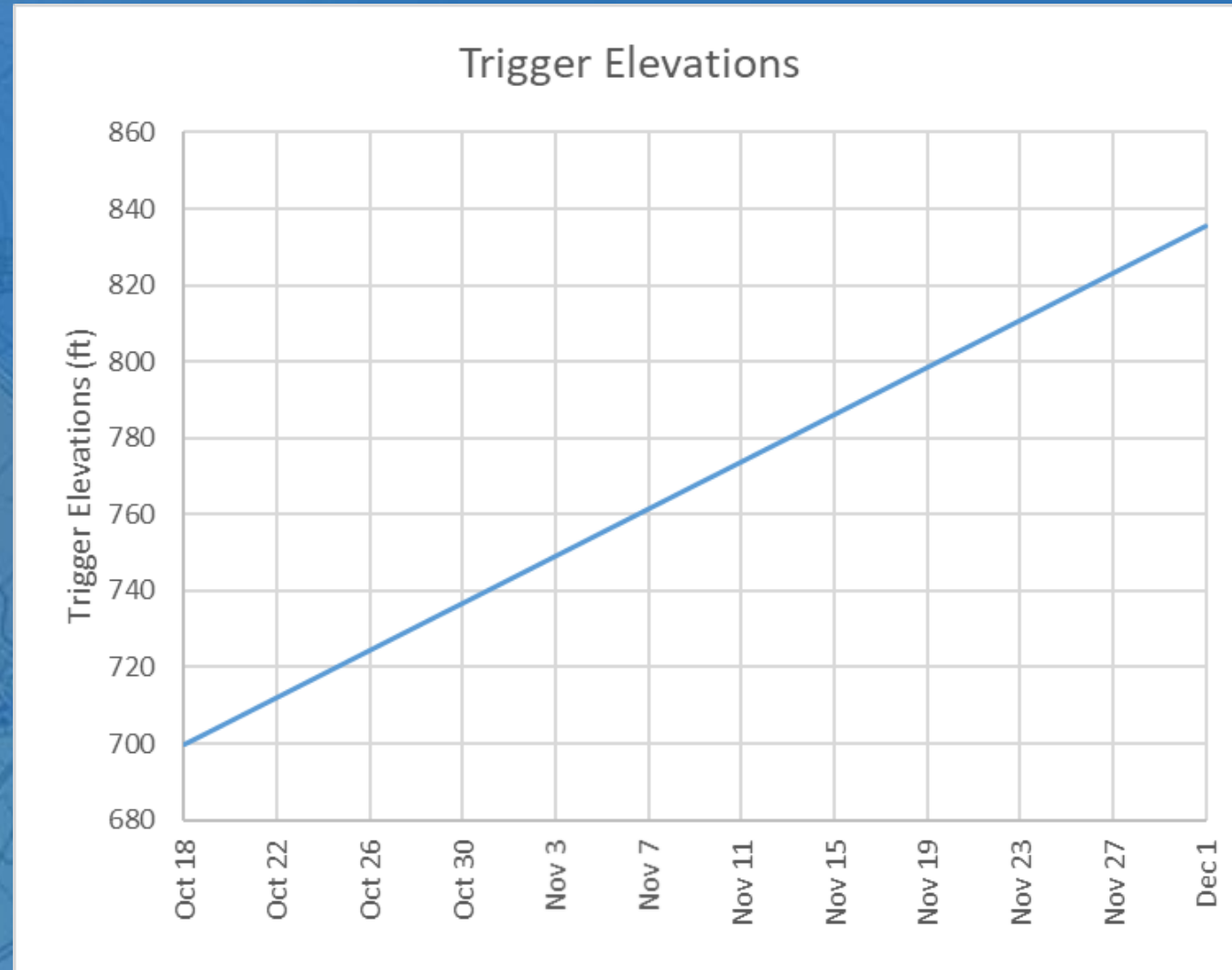
# 2018-19 Winter Operations Plan

- Maintain flood control standards given the construction status of Main Spillway and Emergency Spillway
- Main Spillway becomes operational December 1, 2018
  - Moderate elevation gains with storage triggers mid-Oct to Dec
- Emergency Spillway enhancements not complete until spring
  - Manage Standard Project Flood (SPF):
    - Without use of the Emergency Spillway
    - While maintaining WCM downstream flow requirements
  - Achieve this objective by:
    - Enhancing existing flood pool during winter months



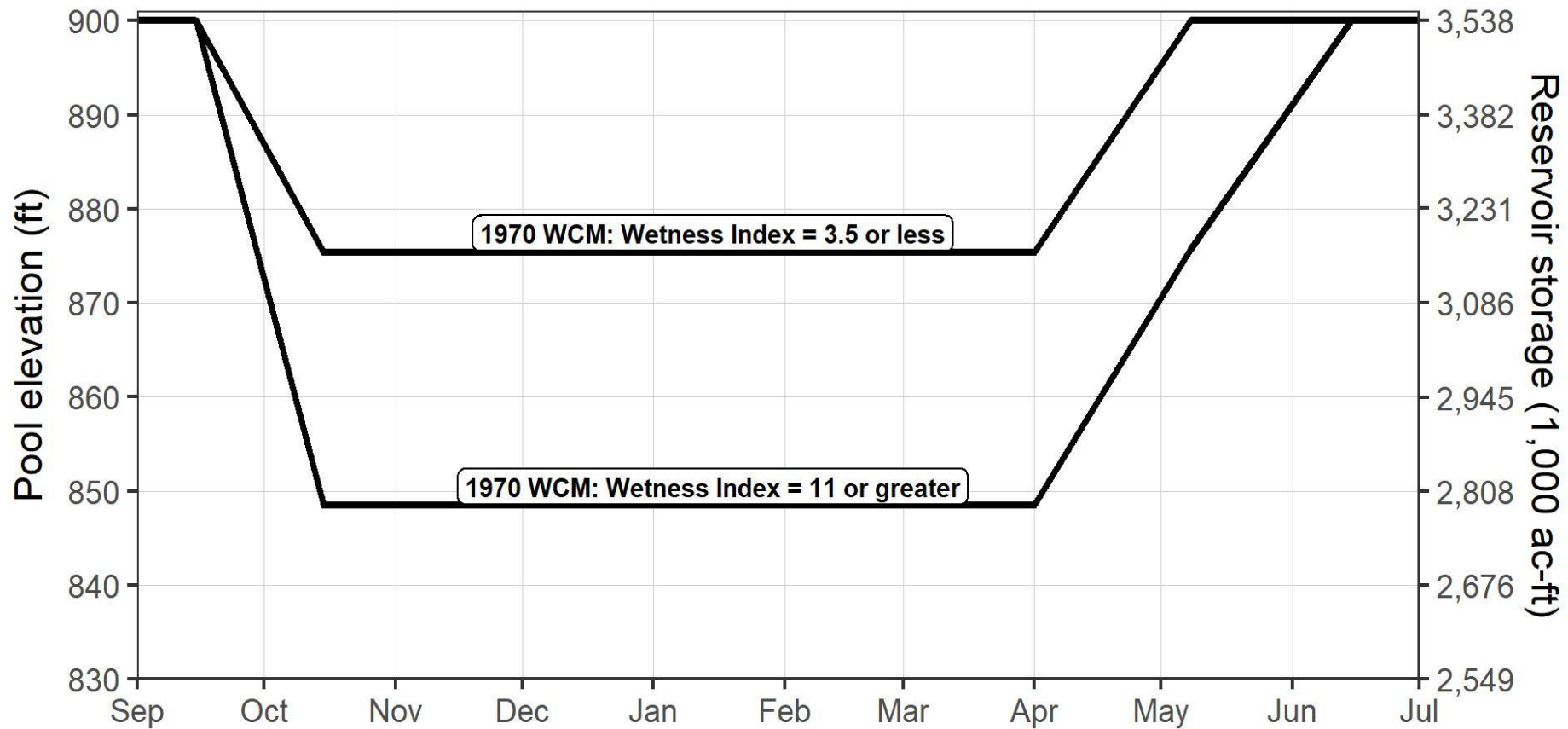


# Elevation Triggers Prior To Main Spillway Recommissioning



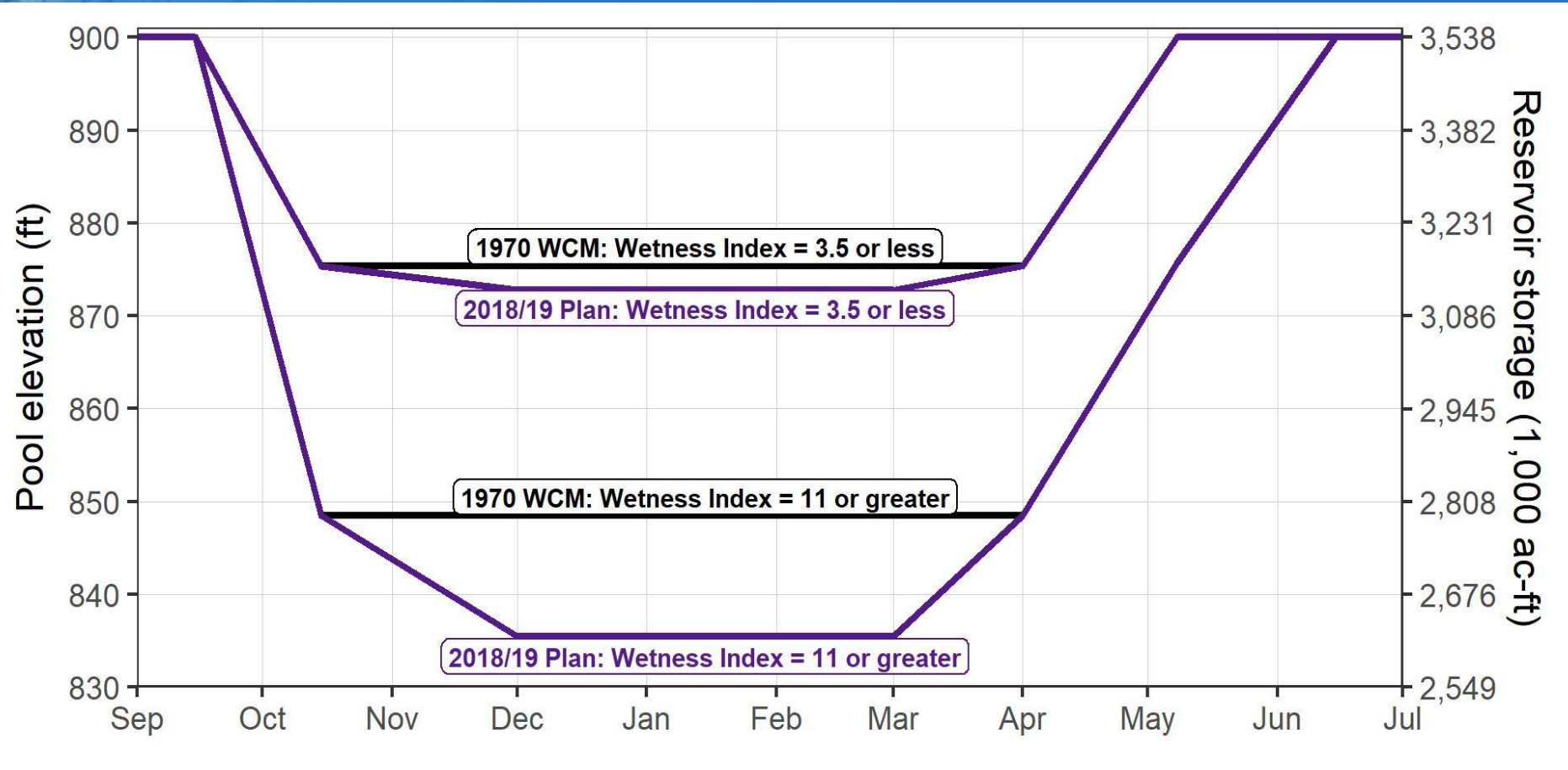


# Existing WCM Flood Pool





# Enhanced Flood Pool (DRAFT)



The informal interim flood operations plan enhances the dry watershed flood pool by 37 TAF and the wet watershed flood pool by 170 TAF.





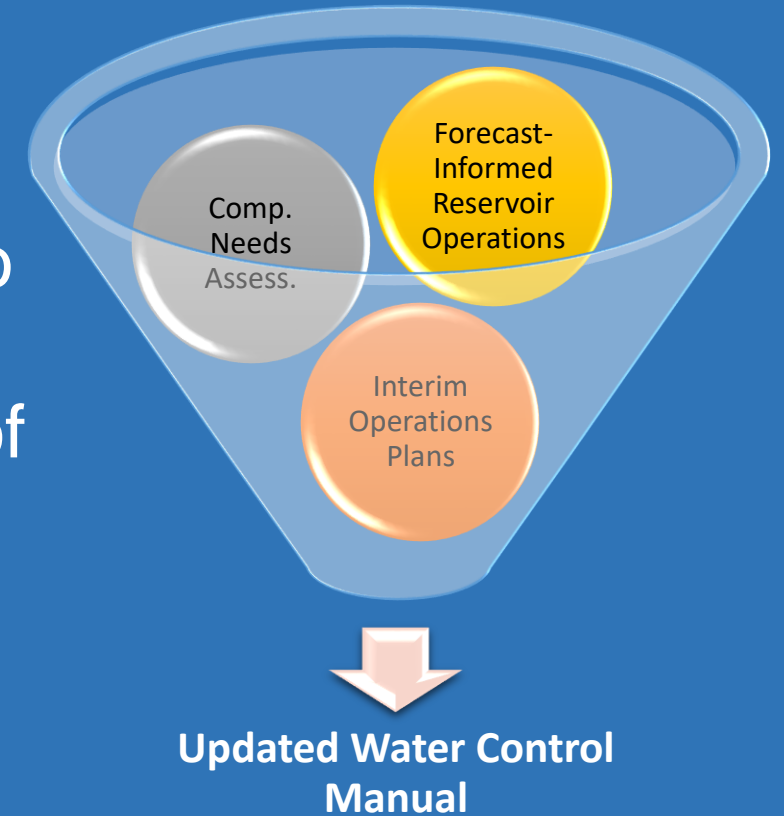
# CNA – Task 2

- Compare CNA alternatives to operations without infrastructural improvements (baseline operations)
- Inform CNA alternative rankings based on operational metrics
- Incorporate any CNA adopted infrastructural changes into USACE Water Control Manual update process



# USACE WCM Update

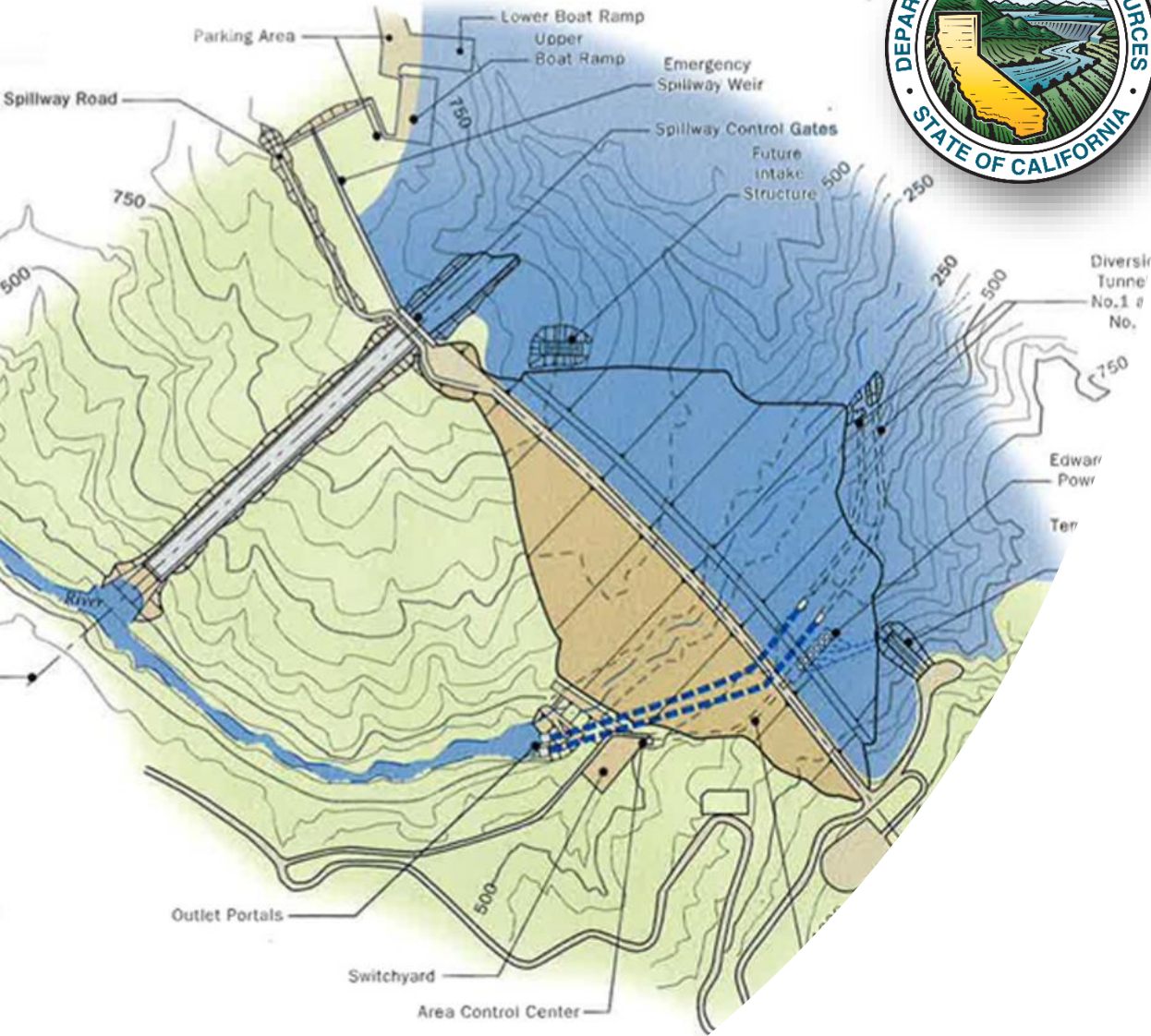
- Multi-year activity beyond CNA
- Use adopted CNA alternatives to inform formal WCM update
- Anticipate the following as part of the USACE process:
  - Updated hydrologic record
  - Climate change effects
  - Forecast-informed operations
  - Re-assessment of downstream requirements
  - Coordination with partner agencies





Questions?





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# Task 3 Flood Control Outlet Enhanced Reliability

**Oroville Dam Safety Ad Hoc Committee  
Meeting No. 2**

**October 30, 2018**





# What is Task 3?



- An overall assessment of the Flood Control Outlet that focuses on achieving long-term reliability of the facility.
- Includes operating systems and the FCO's major structural components:
  - New Spillway Chute
  - Gate Structure
  - Adjacent Monoliths
  - Radial Gates





# CNA Fundamental Steps

Step Number	Description of Step
1	Identify objectives, constraints, opportunities, and needs.
2	Identify measures to address those needs.
3	Combine measures to formulate alternative plans.
4	Evaluate alternative plans with agreed-upon metrics.
5	Compare alternative plans.
6	Recommend plans for consideration.

Task 3





# Objective of Task 3

- Enhance the long-term reliability of the Flood Control Outlet.

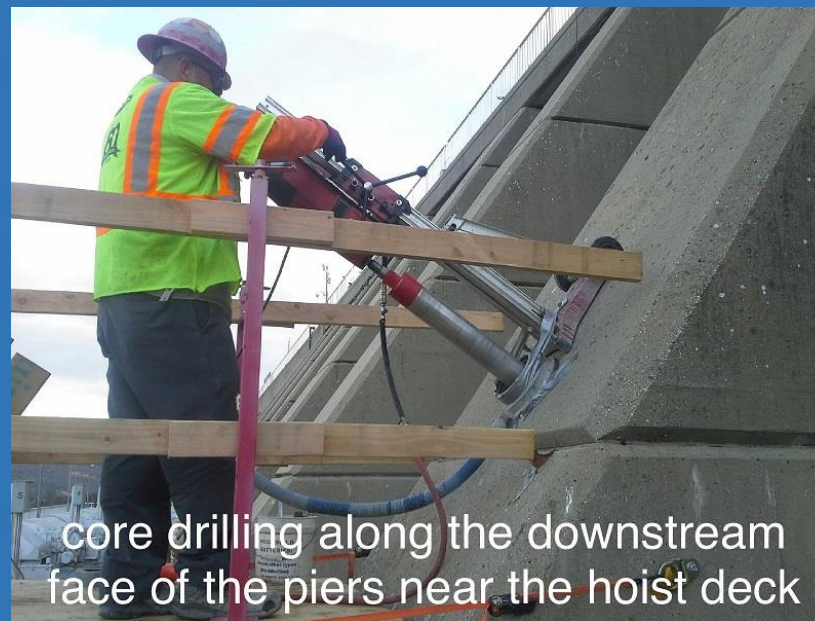
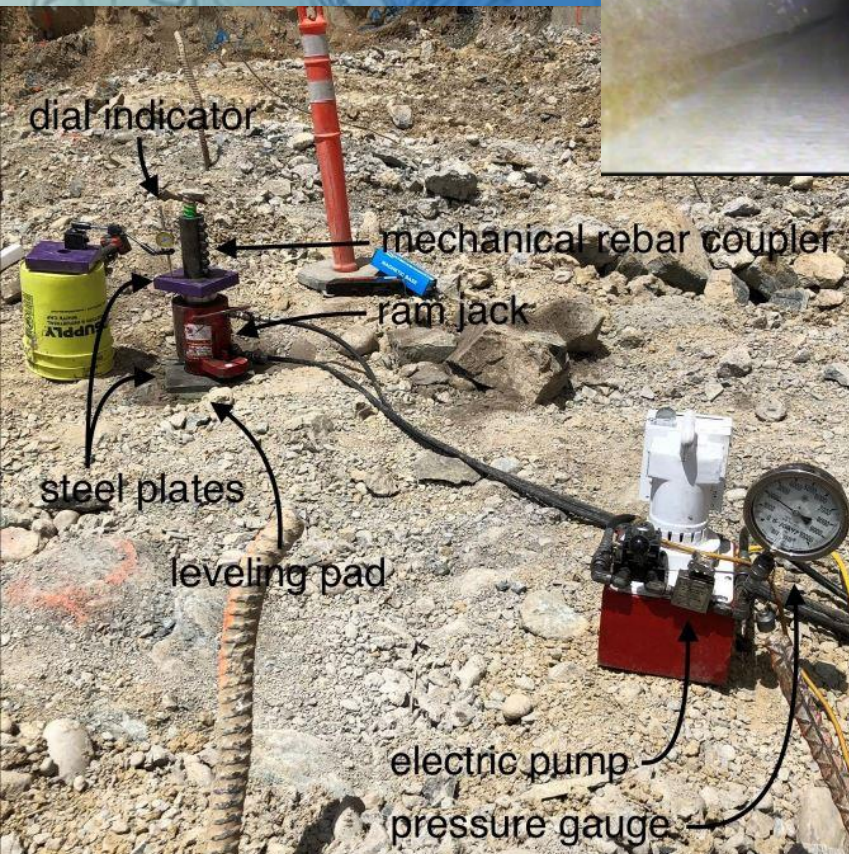
## Constraints

- The FCO is an existing structure:
  - Measures must be carefully screened and evaluated to avoid introducing additional or unintended risk.
  - Measures must be implemented in the context of flood control and water supply needs.
- The FCO has 50+ years of service.
  - Measures should consider what has worked well over that time period.
  - How can we better monitor the condition and performance of its various components over time?



# Opportunity for Data Collection

- FCO drain inspection
- Load-Testing of Existing Anchors just Downstream of FCO
- Sampling and Testing of FCO Concrete and Steel







# Identify Needs through:

- On-going Analyses
- Surveys of Oroville Field Division engineers, mechanics, electricians, and operators.
- Inspections
- Documentation Review and Improvement
  - O&M Manuals and Practices
  - Operation Orders & Instructions
- Level 2 Risk Analysis

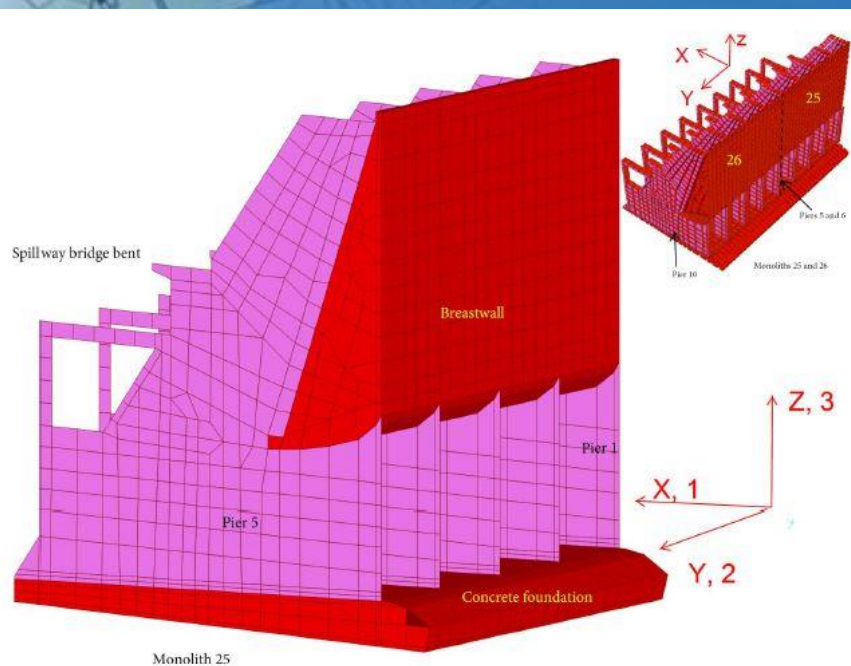


Figure 2-2. FCO Finite Element Model, Coordinate System, and Piers



# Leverage Recent Analyses and Inspections



- 2011 Structural Re-Evaluation of Radial Gates
- 2012 Rope Access Structural Inspection
- 2014 Structural Re-Evaluation of Radial Gates
- 2017 Multiple Rope Access Structural Inspections (during zero flow periods)
- 2017 Radial Gate Maintenance
- 2017 – 2018 Structural Analyses
- Recent Faulting and Seismicity Studies
- Annual Gate Exercises
- Periodic Balance Checks of Hoist Ropes



# Operating Systems and Procedures



- Identify and document redundancy and resiliency of power sources
- Identify critical operational equipment and their condition, availability of replacement parts, etc.
- Review and assess operational procedures for gate operations.
- Assess stop log needs and operations.





# How Will This be Used in CNA?

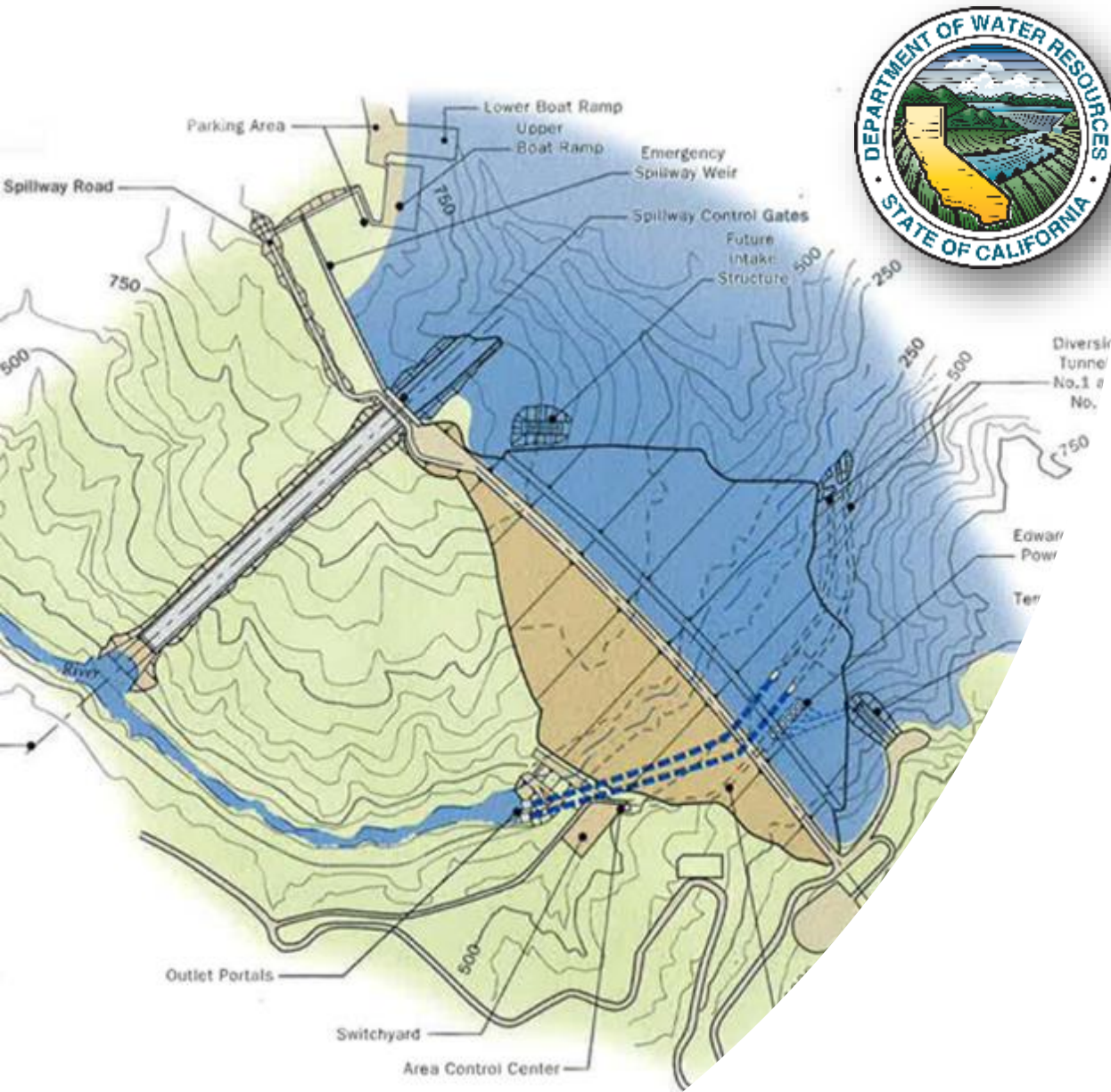
- Measures identified for the FCO will be integrated with those of other tasks
- Identify periodic condition assessment and inspection requirements
- The FCO provides for robust flood control releases. We anticipate many FCO measures to be components of the proposed integrated plans.
- Task 3 could identify smaller measures that would be readily implementable.







Questions?



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# Task 5 Status Update

**Oroville Dam Safety Ad Hoc Committee Meeting No. 2**

October 30, 2018







# Task 5: Oroville Dam Embankment Reliability and Improvements

## Background

Embankment reliability studies had already been initiated in response to the 2014/2015

***“Ninth FERC Five-Year Part 12D Report”***







# 2014/2015 Part 12D Recommendations

**R-10**

*“The Board reiterates that the monitoring and analysis of seepage (including turbidity) are vital aspects of understanding the behavior of the dam, particularly because very limited piezometric data are being recorded in the dam...”*

Sub-bullets R-10a through R-10h provide further detail.

**R-18**

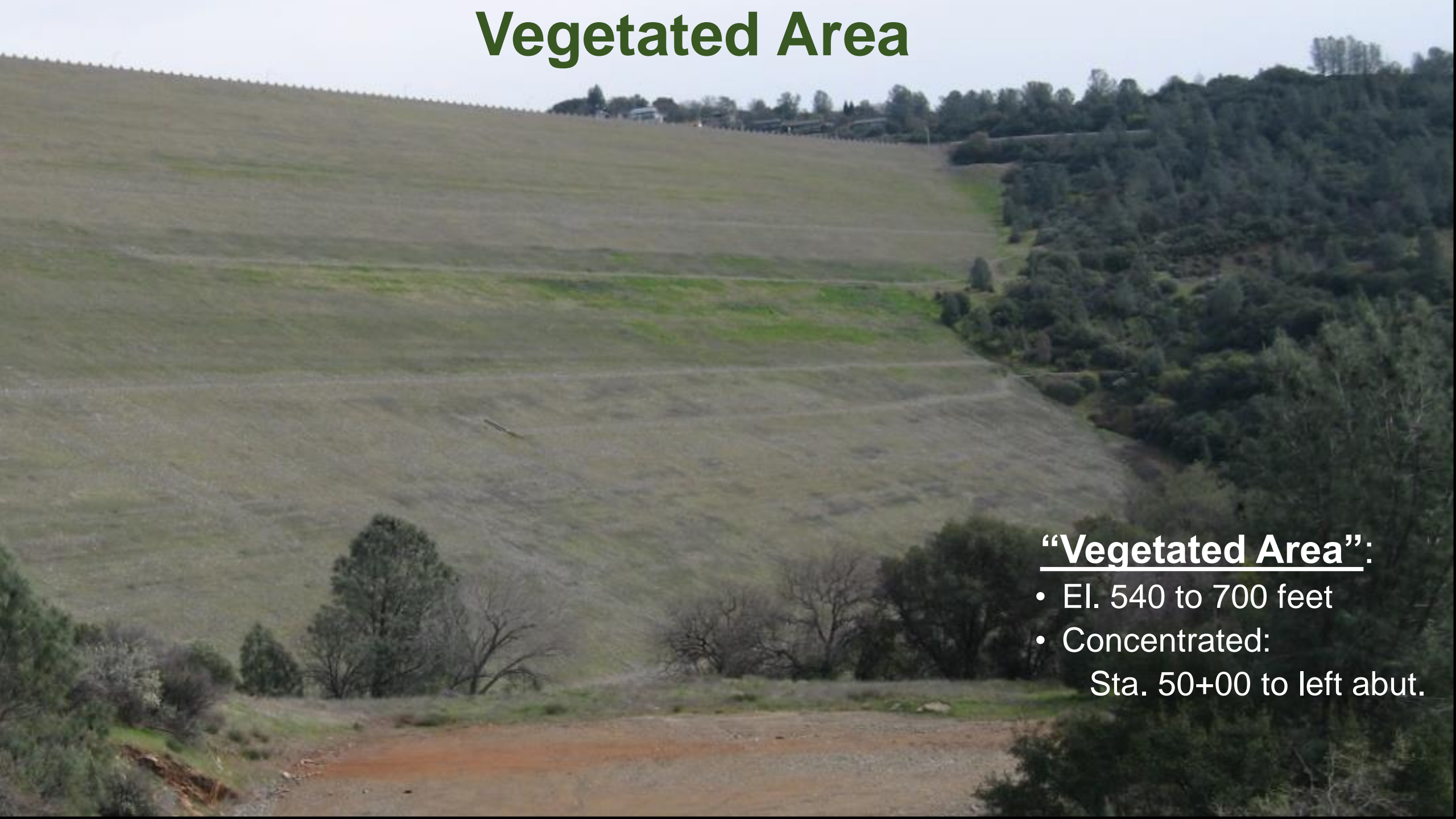
*“The Board recommends that the issue of potential instability associated with the green spot on the downstream face of the dam toward the left abutment between El 600 and El 700, approximately, be investigated...The investigation..., should include computational analyses to asses the effects of such a zone on the static and seismic stability of the dam...”*

# Vegetated Area





# Vegetated Area



## “Vegetated Area”:

- El. 540 to 700 feet
- Concentrated:  
Sta. 50+00 to left abut.

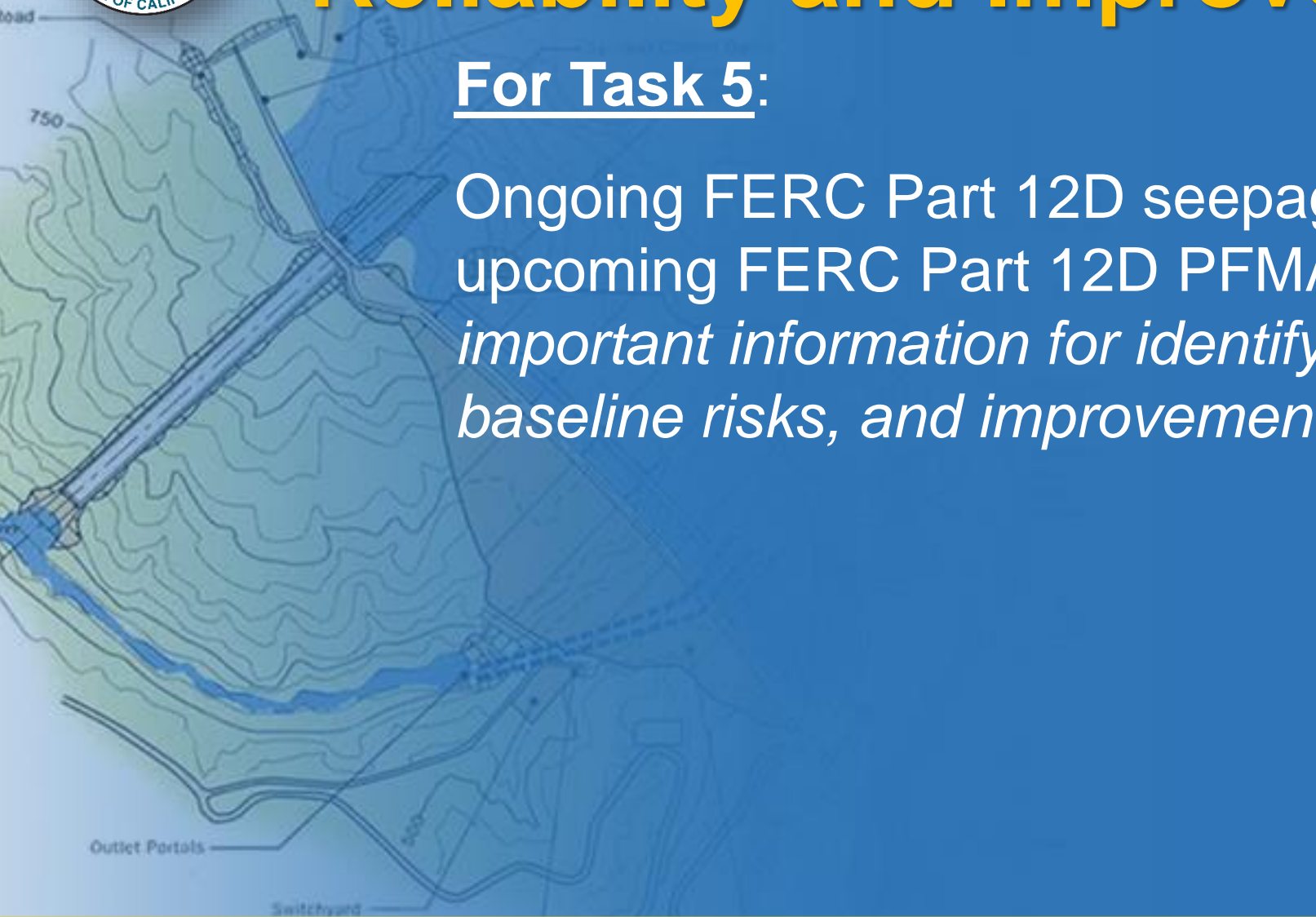




# Task 5: Oroville Dam Embankment Reliability and Improvements

## For Task 5:

Ongoing FERC Part 12D seepage and stability studies, and upcoming FERC Part 12D PFMA/Level 2 RA, *will provide important information for identifying existing conditions, baseline risks, and improvement needs for Task 5.*





# Merging Embankment Reliability into Comprehensive Needs Assessment



# CNA Fundamental Steps

Step Number	Description of Step
1	Identify objectives, constraints, opportunities, and needs
2	Identify measures to address those needs
3	Combine measures to formulate alternative plans
4	Evaluate alternative plans with agreed-upon metrics
5	Compare alternative plans
6	Recommend plans for consideration

*A Water Resources Planning Approach*





# Task 5 Step 1 – Current Status

Identify objectives, constraints, opportunities, and needs





# Step 1: Identify Problems and Objectives

## Previous FERC Part 12D

- R-10 Embankment and foundation seepage (potential for internal erosion and piping).
- R-18 Embankment stability
  - Local stability at “*Vegetation Area*”
  - Overall stability under normal, flood and seismic loading conditions.

## Upcoming FERC Part 12D PFMA/Level 2 RA

- Identify Additional Problems/Issues/Potential Risk Reduction



# Most Notable Historical PFMs

- Zone 1 Core material piping through broken instrumentation tubes, leading to dam failure.
- Failure of Palermo Tunnel Outlet, leading to erosion of left downstream groin and failure of dam.
- Internal erosion of Zone 1 Core due to filter incompatibility with Zone 2 Transition.
- Embankment erosion under flood loading along FCO Monolith 31.
- Potential instability associated with "*Vegetated Area.*"





# Step 1 – Identify Constraints

## Examples of Constraints

- ✓ Existing as-constructed structure
- ✓ Embankment zone engineering properties
- ✓ Embankment seepage/phreatic surface
- ✓ Limited number of piezometers
- ✓ Seismic and flood loadings
- ✓ Aging analytical evaluations



# Existing Conditions, Issues and Uncertainties

- Variability/uncertainty of material properties in dam materials.
- Filter compatibility between the core and filter materials.
- “Vegetation Area” on dam face.
- Toe seepage measurements obscured by rain infiltration.
- Broken piezometer tubing for piezometers in core and other embankment zones.
- Need for more sophisticated seepage modeling.
- Need for more sophisticated stability modeling.
- Potential issues at Embankment Dam/FCO Monolith 31 Interface.

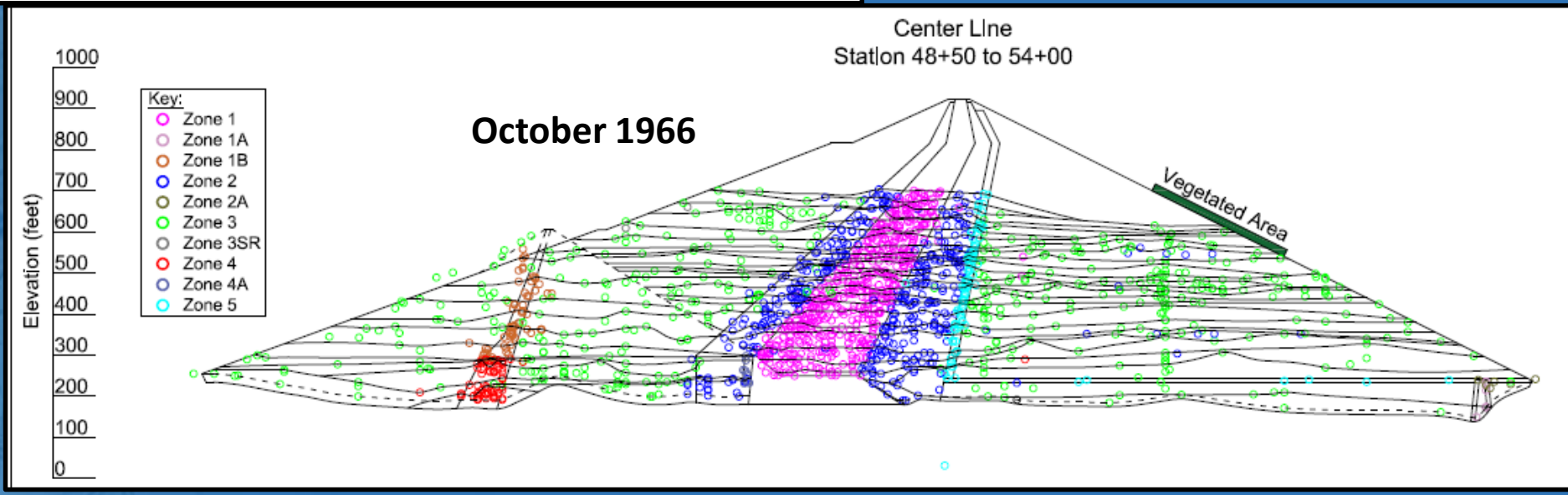
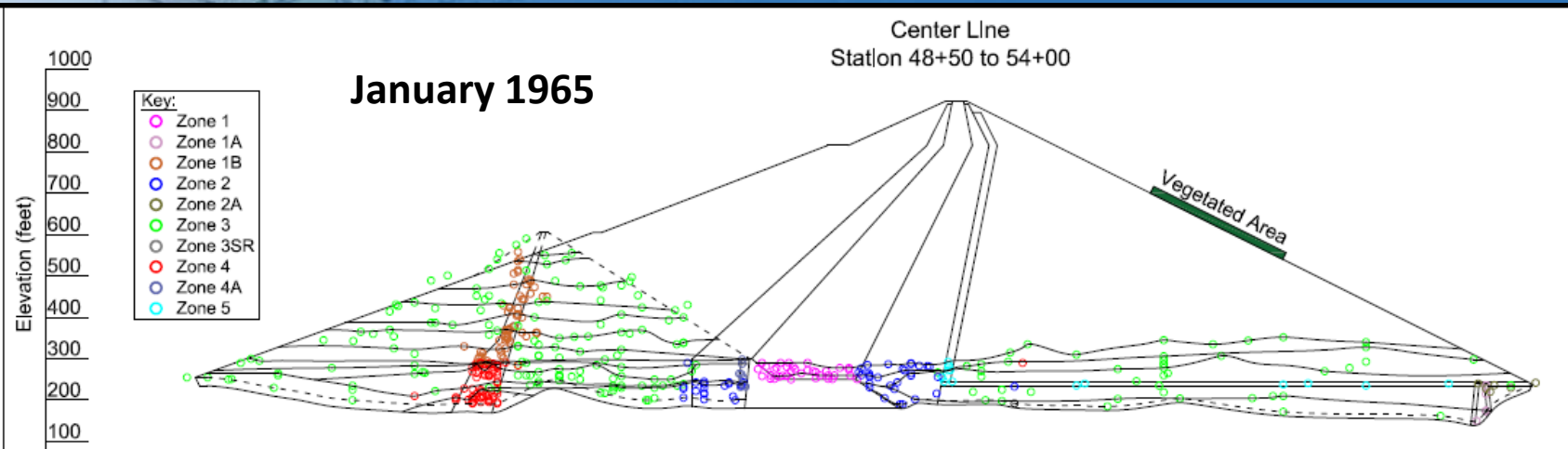
# Progress of Select Sub-Tasks

Number	Subtask Description	Status
2	Collect, summarize, and review geotechnical design, construction, and performance data of the embankment materials and foundation	100% Complete
3	Review filter compatibility between dam materials and assess the potential for internal erosion	99% Complete
4	Review case histories of internal erosion for dams relevant to Oroville Dam	100% Complete
5	Complete an analysis of rainfall impacts on historical seepage data	95% Complete
8	Perform seepage analyses through/beneath Oroville Dam	50% Complete
11 & 12	In relation to the “Vegetated Area,” develop material property statistics, and identify area limits of seasonal changes	98% Complete
13	Perform 2D and 3D slope stability analyses to evaluate potential sliding surfaces within the “Vegetated Area”	Ongoing
15	Review seepage and stability reliability of Parish Camp and Bidwell Bar Canyon Saddle Dams	Recently Started
16	Review seepage and stability reliability of the right abutment portion of the dam embankment that wraps around FCO Monolith 31	Recently Started



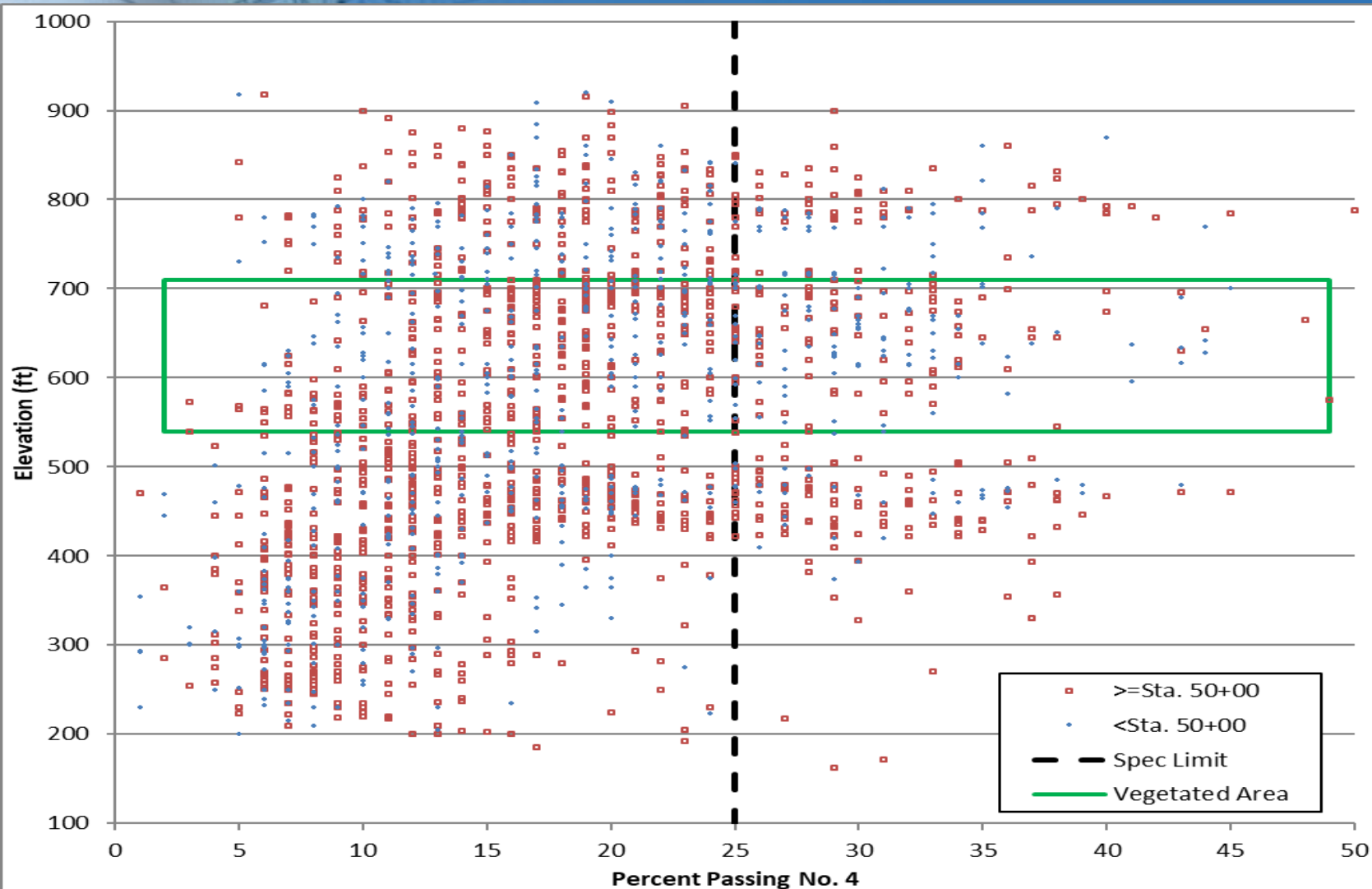


# Material Properties: Filtered and Plotted vs. Time and Space





# Variability of material properties in dam materials



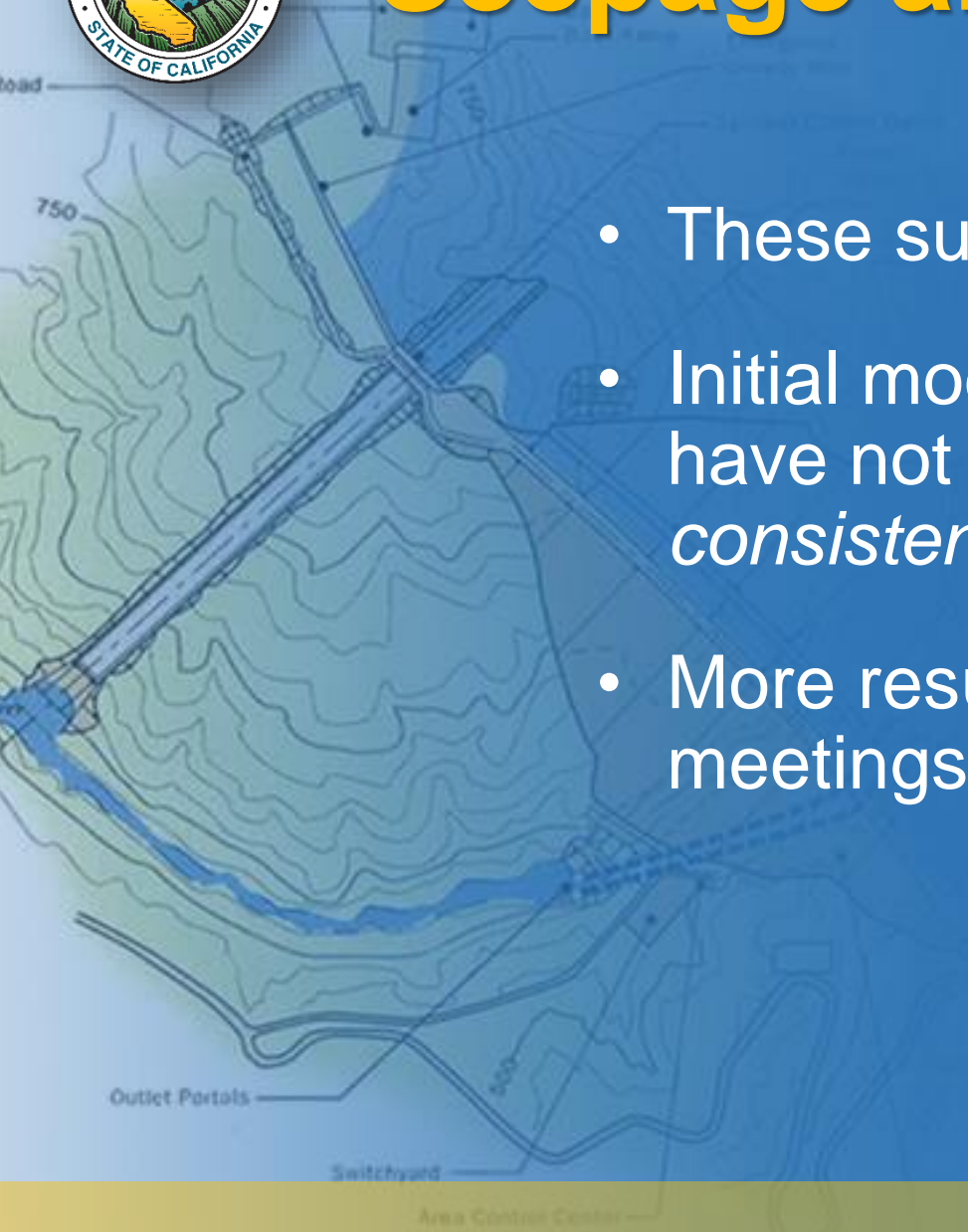
- Developed material properties database.
- Data includes:
  - Gradations
  - Specific gravities
  - Field densities
  - Maximum densities
  - Atterberg limits
  - Hydraulic conductivities
- Metadata includes:
  - Elevation, Stationing, and offset

Example Plot: Percent passing No. 4 sieve for Zone 3 (entire dam – points separated for Left and Right Sides)



# Seepage and Stability Modeling

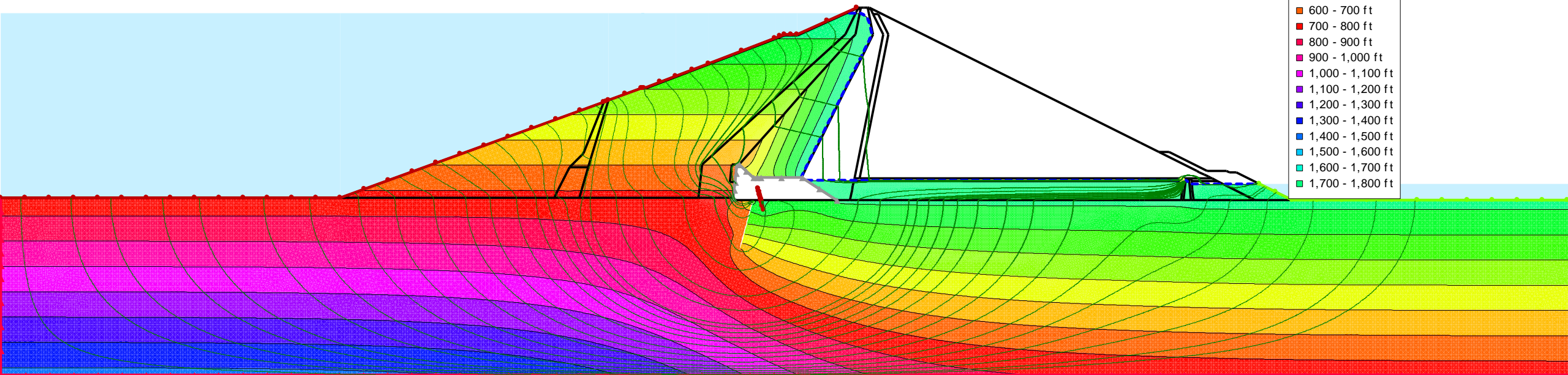
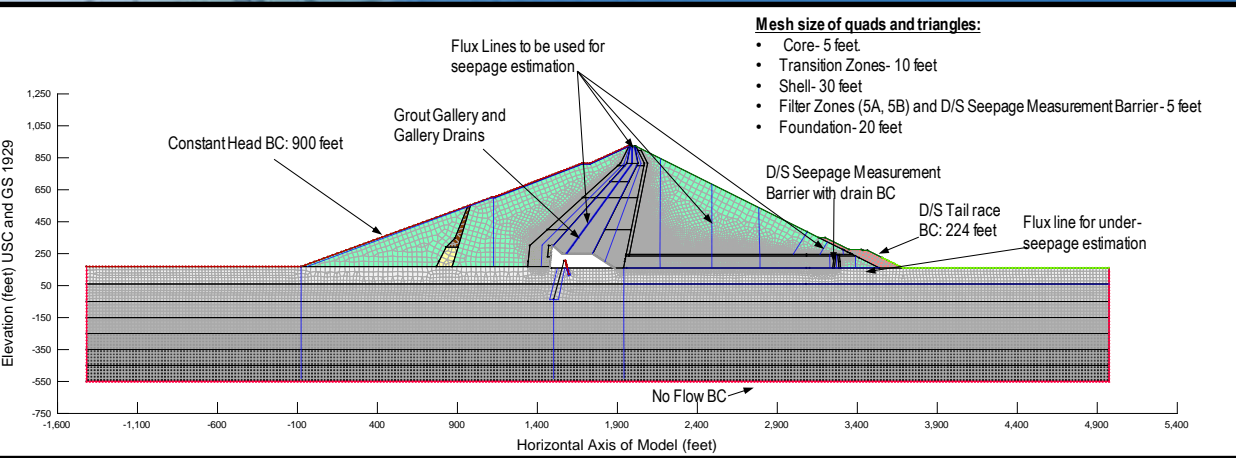
- These sub-tasks are still in their early stages.
- Initial modeling and performance measurements have not identified any unexpected issues – *consistent with design expectations of performance*
- More results will be available in subsequent meetings.







# Steady State Seepage 2D Model: Initial Results, Total Head Contours and Flow Paths Maximum Section – Reservoir Elevation 900 feet

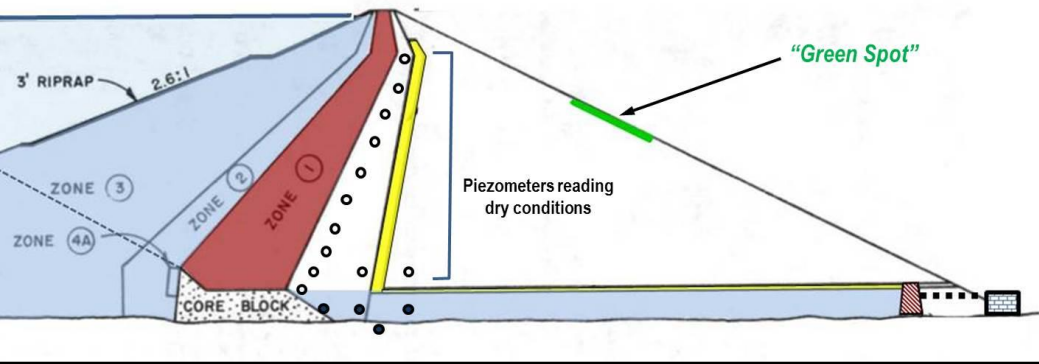






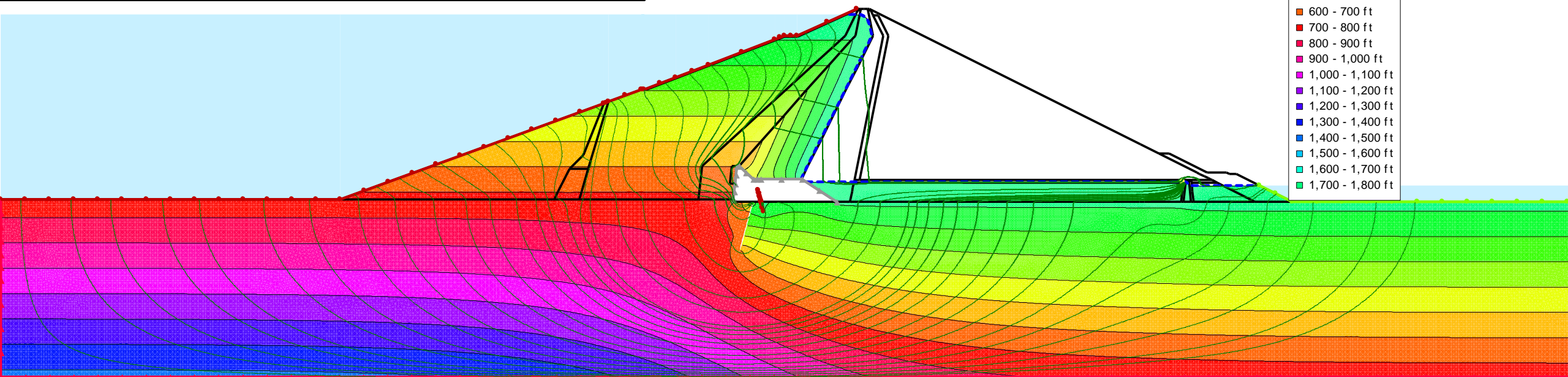
# Steady State Seepage 2D Model: Initial Results, Total Head Contours and Flow Paths Maximum Section – Reservoir Elevation 900 feet

- Downstream Piezometer indicating Dry Conditions
- Downstream Piezometer indicating Low Seepage Pool Water Level



## Pressure Head

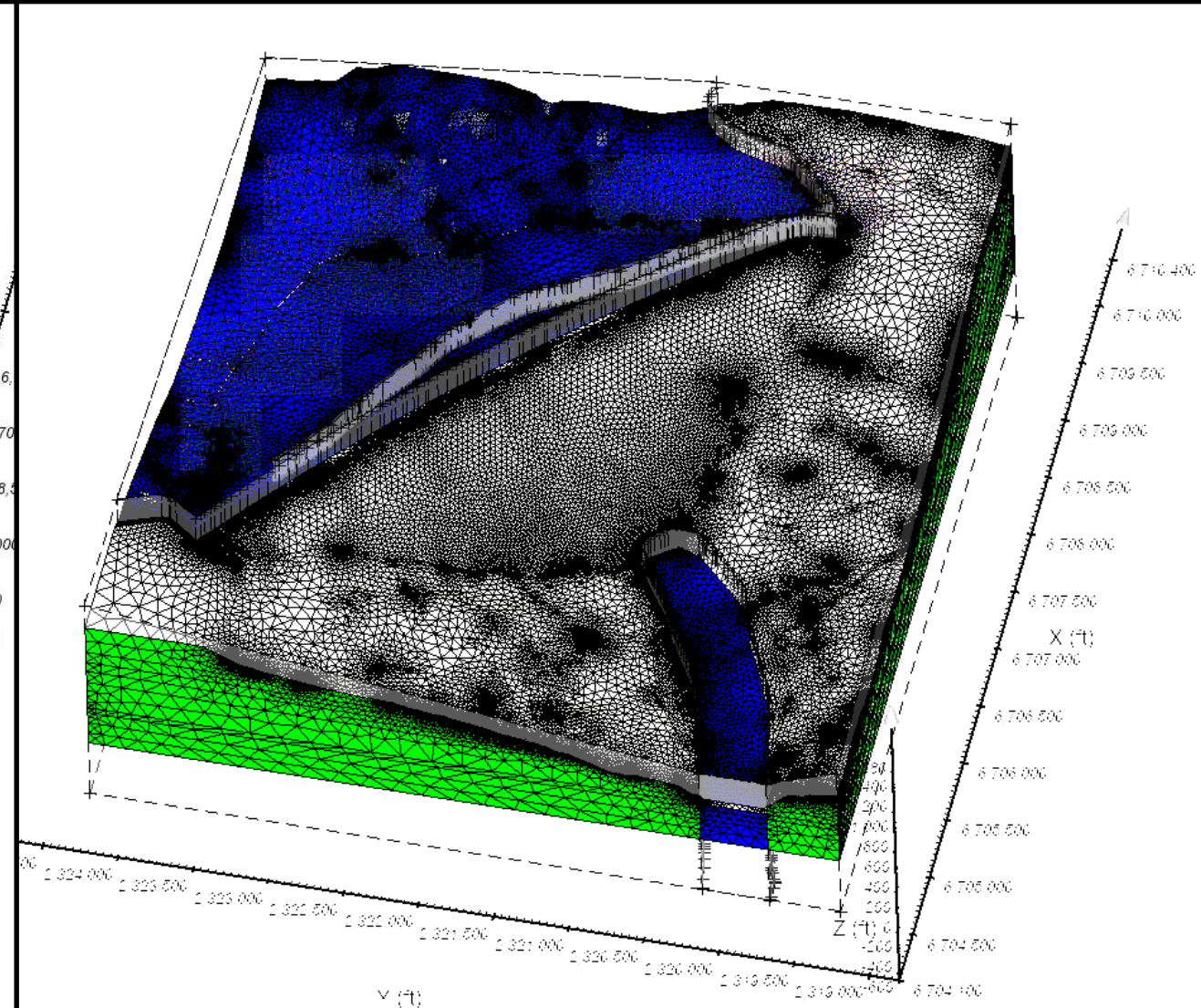
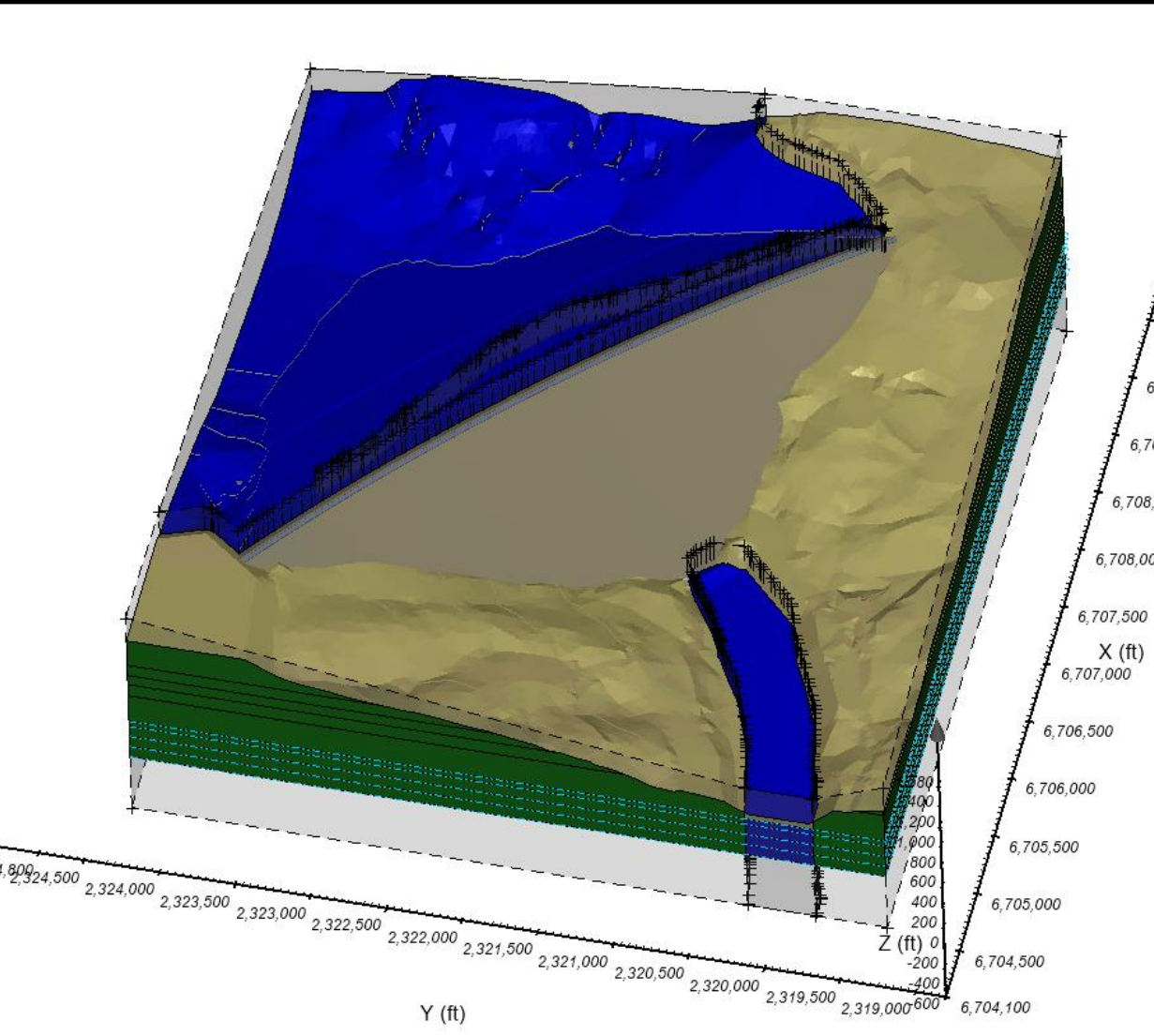
0 - 100 ft
100 - 200 ft
200 - 300 ft
300 - 400 ft
400 - 500 ft
500 - 600 ft
600 - 700 ft
700 - 800 ft
800 - 900 ft
900 - 1,000 ft
1,000 - 1,100 ft
1,100 - 1,200 ft
1,200 - 1,300 ft
1,300 - 1,400 ft
1,400 - 1,500 ft
1,500 - 1,600 ft
1,600 - 1,700 ft
1,700 - 1,800 ft







# Steady State Seepage 3D Model





# Vegetated Area



Seepage on the downstream dam face, prior to reservoir filling  
January 6, 1967





Downstream Zone  
3. Approximately  
El. 660'

# Vegetated Area

- Photo of ponding near Vegetated Area.
- Very wet winter of 1966/1967.

Low spots,  
ponding









# Next Steps

- ✓ Complete FERC Part 12D Seepage/Stability Subtasks
- ✓ Use results of studies to inform upcoming FERC Part 12D PFMA/Level 2 Risk Analyses
- ✓ Use as part of basis for identifying potential improvement ***Measures*** to address opportunities and needs



Questions?